Results from Structure Fabrication at Fermilab

Nikolay Solyak
Fermilab
Technical Division

Outline

- Status of ongoing work
- Progress in FXA-002/3 vs. FXA-001
  - Cell tolerances
  - Mechanical QC, straightness
  - Automation of RF Quality Control and structure tuning
  - Coupler calculation and re-design for FXA-003
- Schedules and future plans
- Summary

NLC R&D Project: Mission Goals

- X-Band Structure Development
  - RF Design and Analysis
- Manufacture Structures in Support of 8-Pack Test
  - RF Testing
  - Production Methods
- Develop Girders in Support of 8-Pack Test

  (Harry Carter presentation)
- Industrialization of X-Band Structure Production

Status of Ongoing Work: X-Band Structures Development

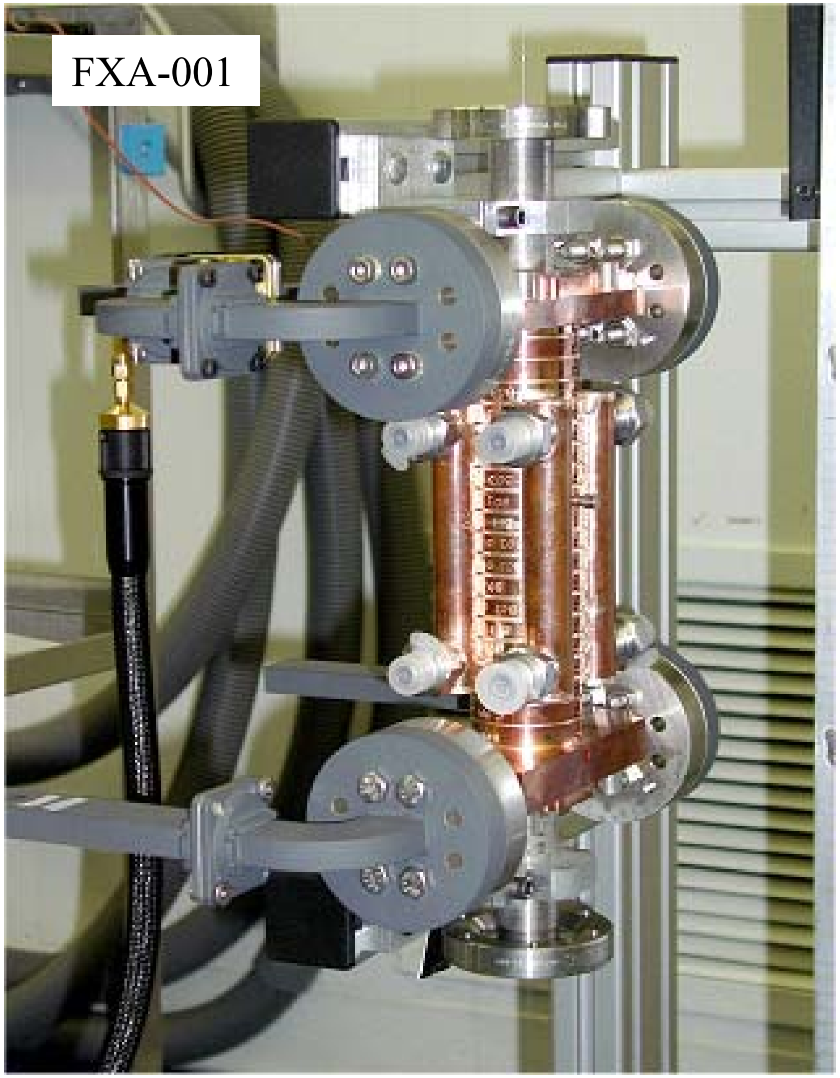
– **RF Design Work**
  - Have Acquired Software and Hardware to Facilitate RF Design and Analysis
  - Have Worked to More Fully Understand the Relationship Between Component Mechanical Design and Electrical Performance

– **RF Testing**
  - Have Developed Single Cell, Bead Pull, and Plunger RF Measurement Hardware and Have Automated the Measurement Process Using LabView

– **Production Methods**
  - Have Conducted Brazing Studies to Optimize Present Joint Design
  - Continuing to Develop the Component Cleaning Process
  - Continuing to Develop Relationships with Component Parts Suppliers
  - Will be Conducting Diffusion Bonding Studies in the Near Future
  - Development of Fixturing and Tooling to Facilitate Structure Assembly

(Borrowed from Harry Carter)

Status of Ongoing Work: X-Band Structures Production

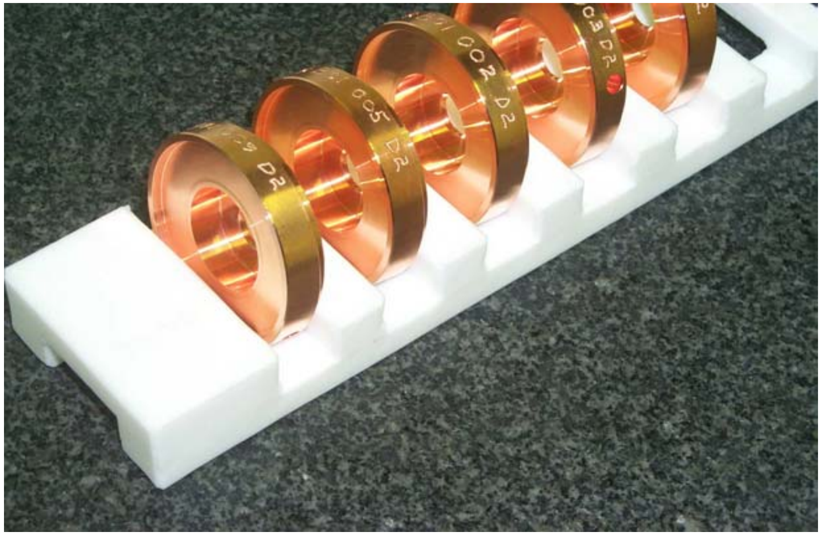


Two FXA-001/2 structures are built, measured and tuned at Fermilab. First structure took a little more than 9 months, second – 2.5months. Target is one structure per month.

We are in the process of producing FXA-003 and FXB-001(thru 003). Both currently delayed due to lack of receipt of Large Vacuum Furnace from AVS.

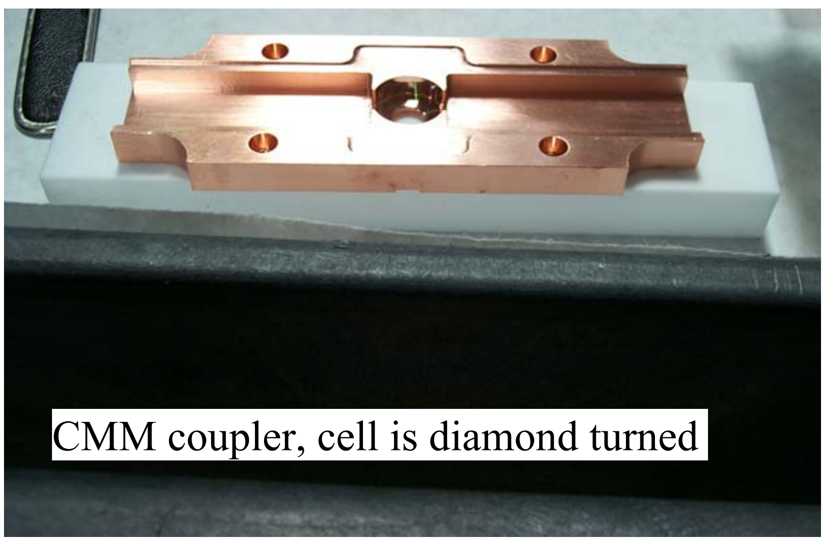
- **FXA** is 20 cm long, $3\pi/2$ structure, made according to SLAC's design of T20VG5 (5% group velocity).
- **FXB** is 60 cm long, $5\pi/6$ structure with 3% group velocity, made for NLC High Gradient Testing.

Cells and couplers production.

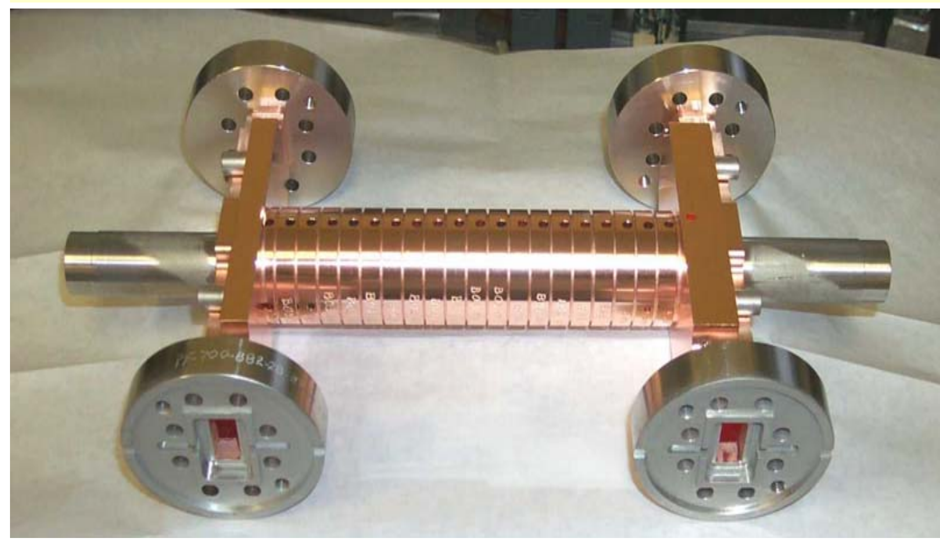


❖ **Parts:**

- 45 mm (61mm) disks from *LaVezzi* and *MedCo.* Disks are not diamond turned … they are high precision conventional turned This is important for keeping the cost down for the main linac.
- Couplers from Contour Manufacturing & Metrology Inc. (CMM), *Owen, Gehard (FXB)*.
- Other Peripheral Components (flanges, water tubes...) from various outside vendors.



CMM coupler, cell is diamond turned

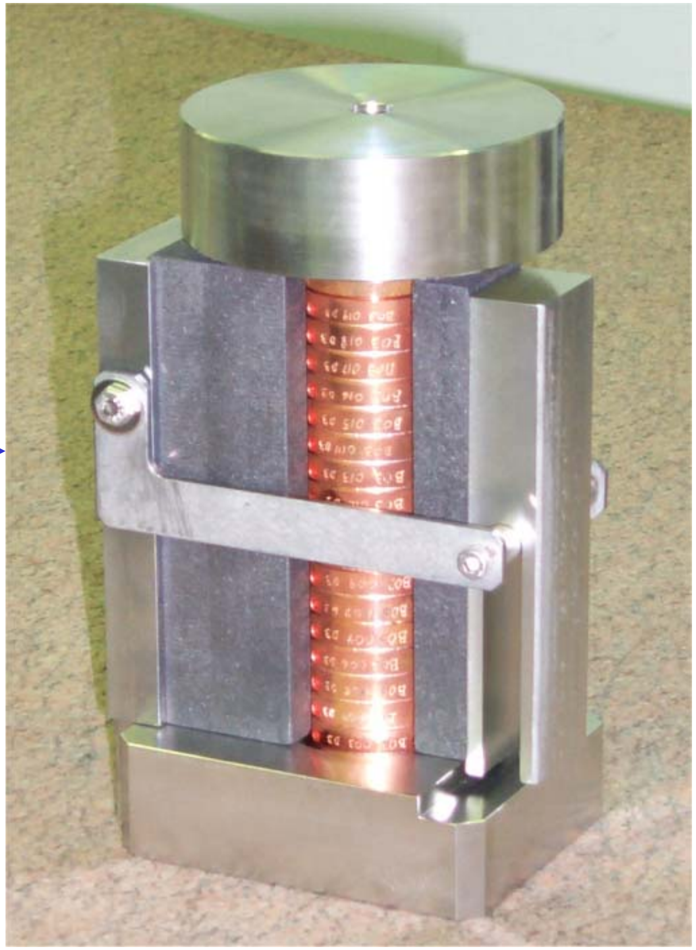


Progress in FXA-002/3 vs. FXA-001

FXA-001 built in Sept.2001. Lessons from this structure help us to improve production of the next FXA and FXB structures.

- Decreasing systematic and random errors in disk dimensions (both Lavezzi and MedCo disks) Systematic error 20 MHz → 2 MHz
- Structure straightness improved (Stack assembly and brazing in carbon V-block)
- Etching process (improving finish cavity surface).
- Automation of RF QC
  (Single disk, plunger, bead-pull)
- Output Coupler design improved (FXA-003)

Fixture with precise carbon V-block



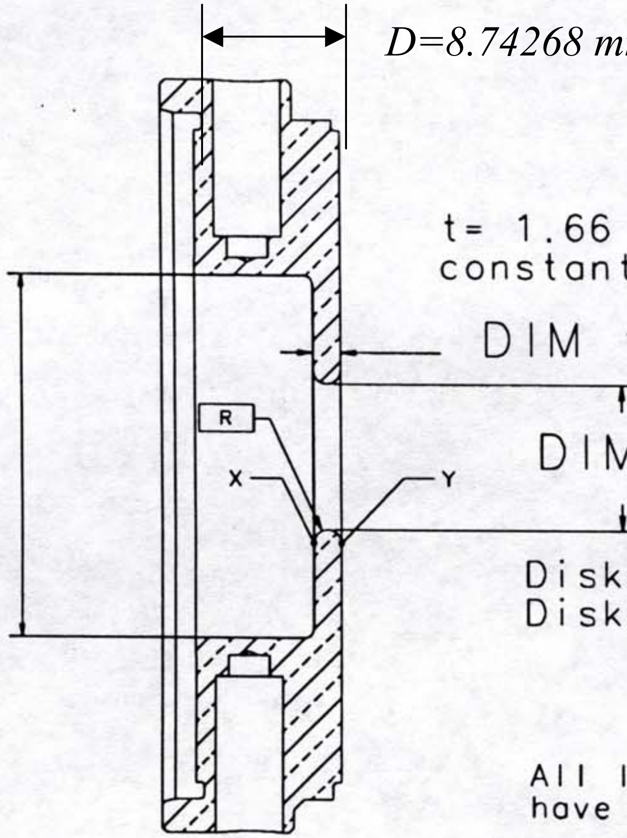
FXA-001 Disk Specifications

- *Conventionally machined disks, tolerances ± 5 μm (± 4.5 MHz)*

FXA-001 RF DISK

RF Disk Frequency Dependency

Delta(f) \ Delta(b) = -1.18 MHz/micron
Delta(f) \ Delta(a) = + 0.5 MHz/micron
Delta(f) \ Delta(t) = - 0.14 MHz/micron



t= 1.66 mm
constant thru Disk#1 to #20

DIM 2b

Disk#1: 2b= 21.746 mm
Disk#20: 2b= 21.605 mm

DIM 2a

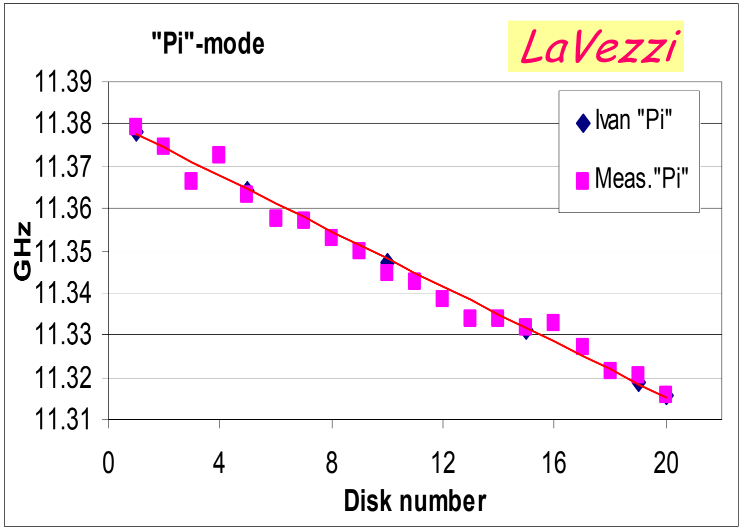
Disk#1: 2a= 8.879 mm
Disk#20: 2a= 8.544 mm

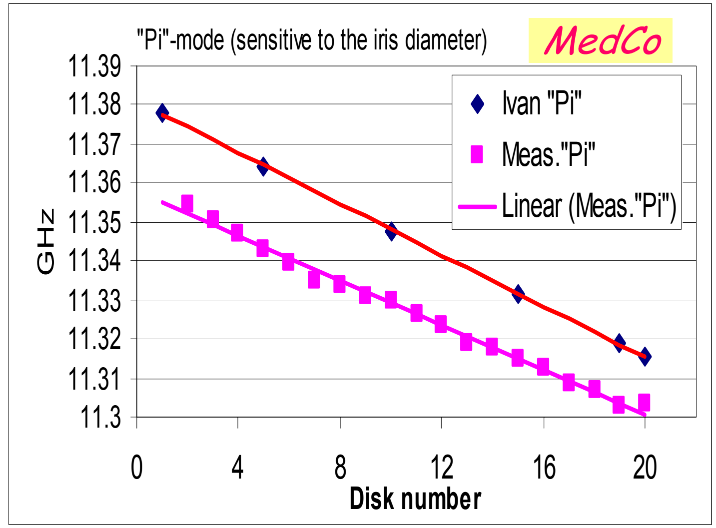
All Iris Dimensions
have +-0.005 mm tolerances

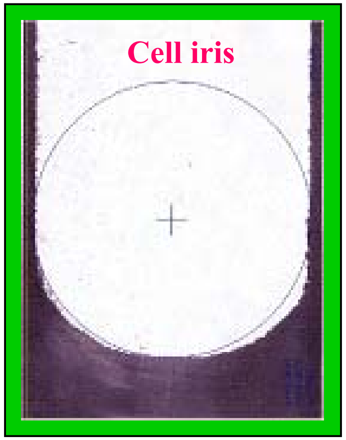
FXA=003 tolerance in (2b) is: -0, +0.010mm

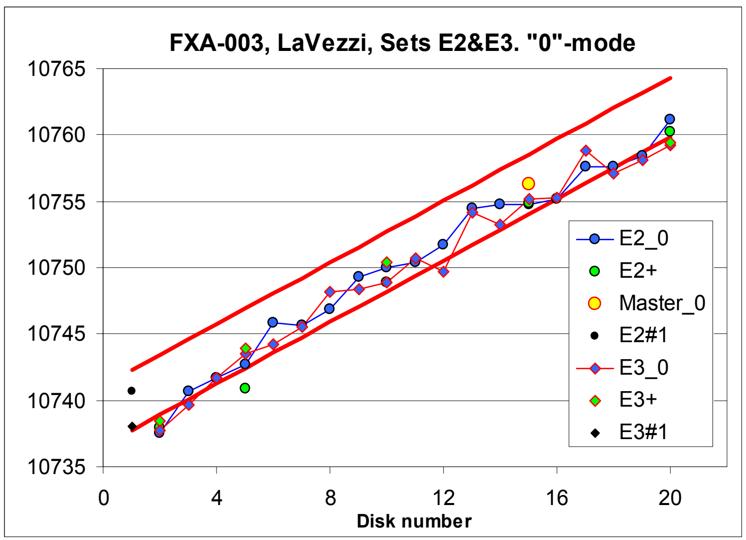
T. Arkan, 10/10/01

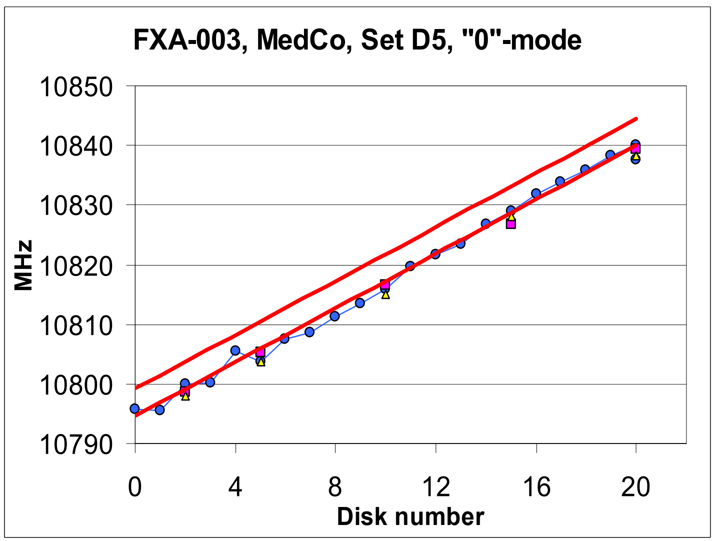
Tolerances improvement in LaVezzi and MedCo disks.











LaVezzi

Random Errors

±5 → ± 4MHz

Systematic Errors

- 3 MHz→?

MedCo

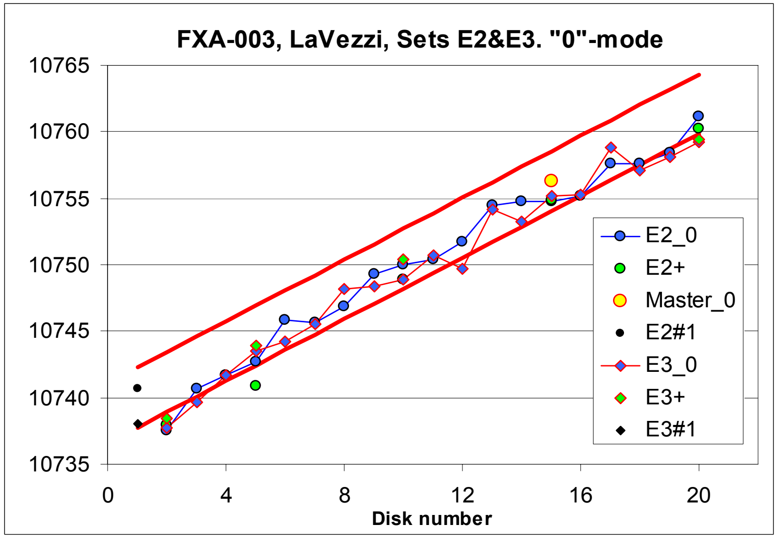
Random Errors

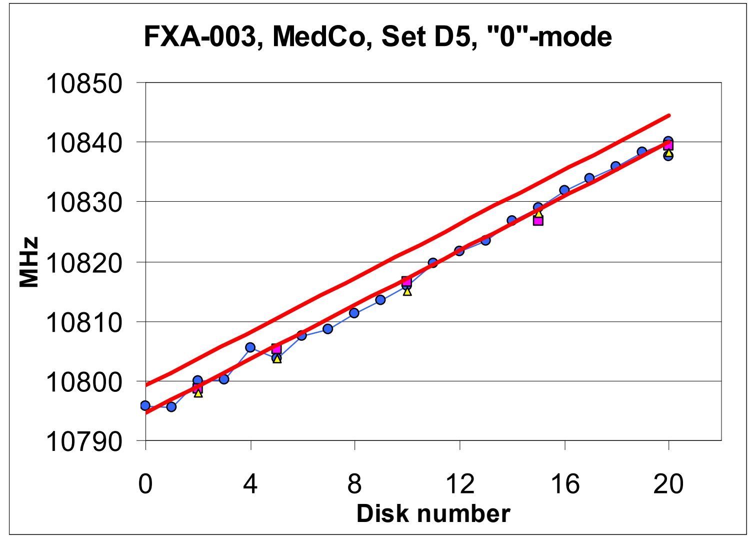
±2 MHz

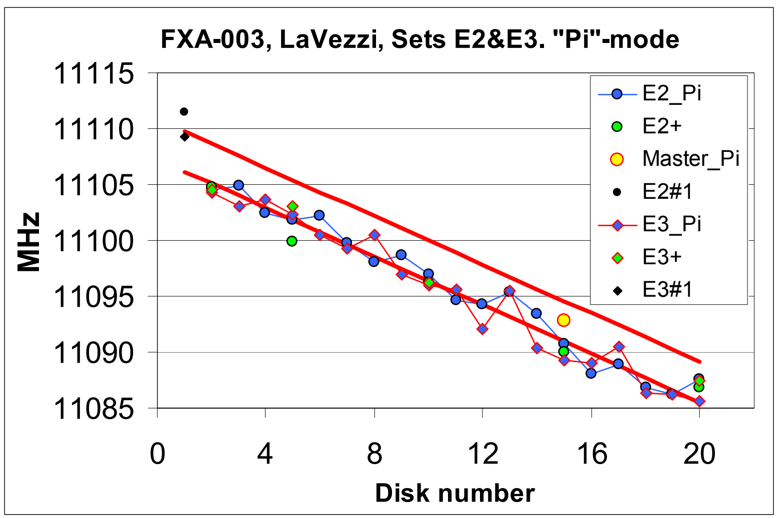
Systematic Errors

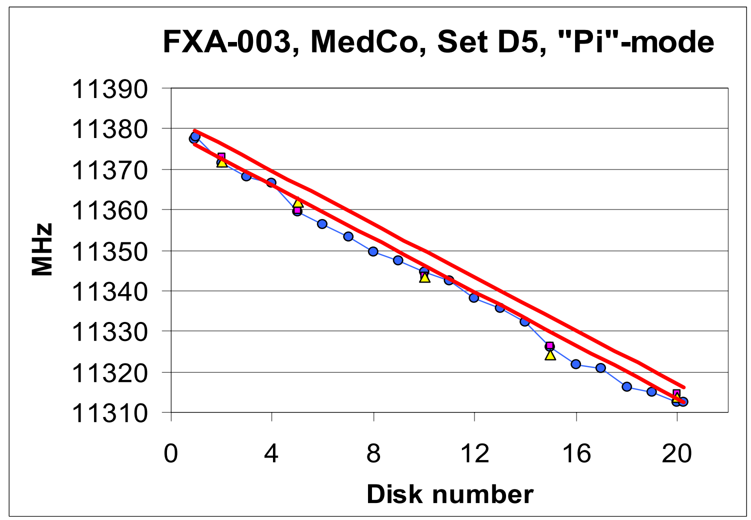
–20 →-4 MHz

Errors in disk sets for FXA-003









Tolerances better than in FXA-001

- Systematic error almost removed
- Random

Lavezzi 4.5-5 MHz

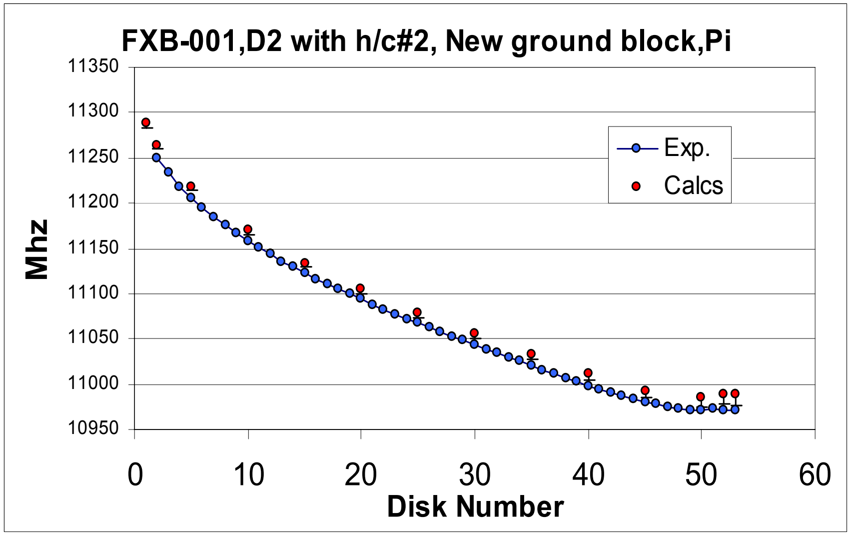
Medco 3 MHz

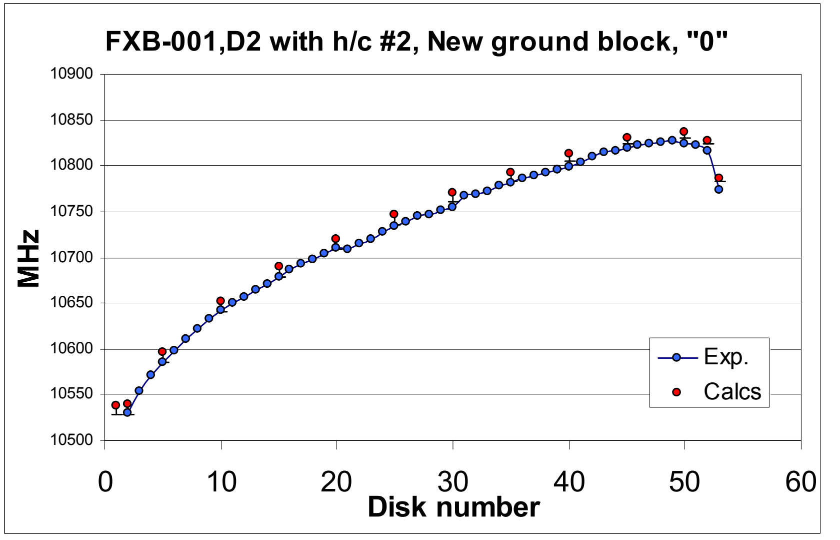
NLC Req.

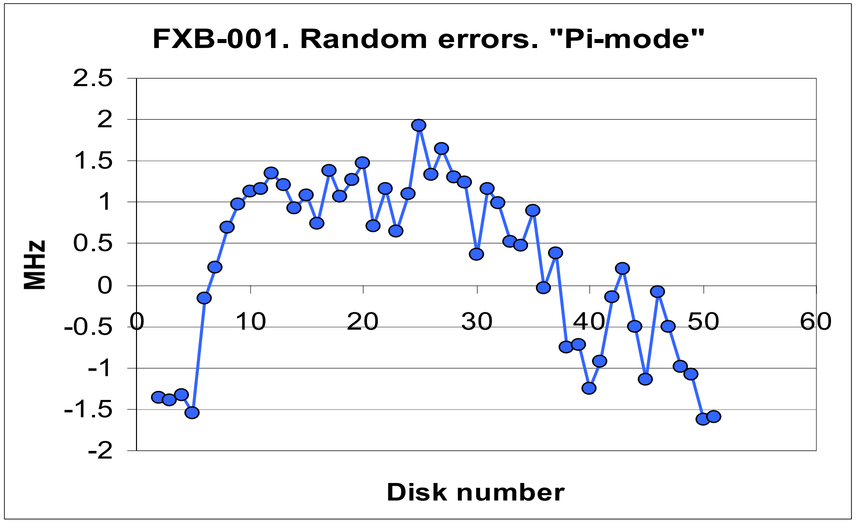
Random ± 3 MHz rms

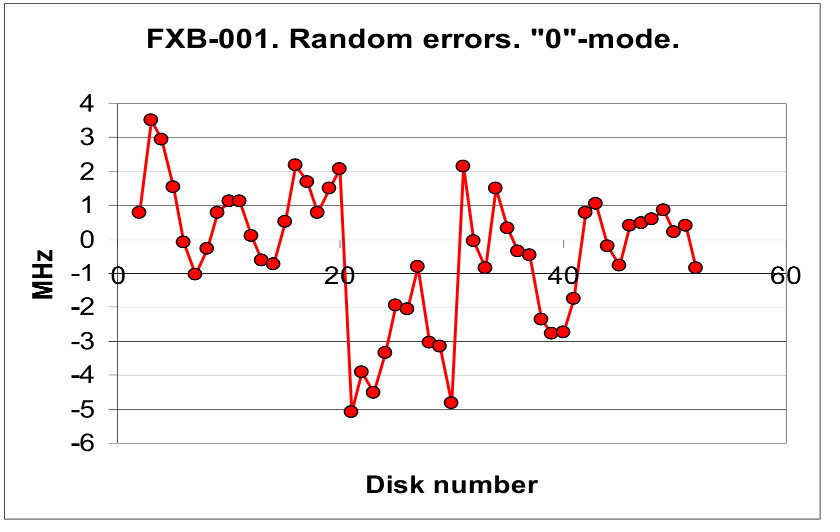
Systematic 1 MHz

Production tolerances of FXB-001 structure





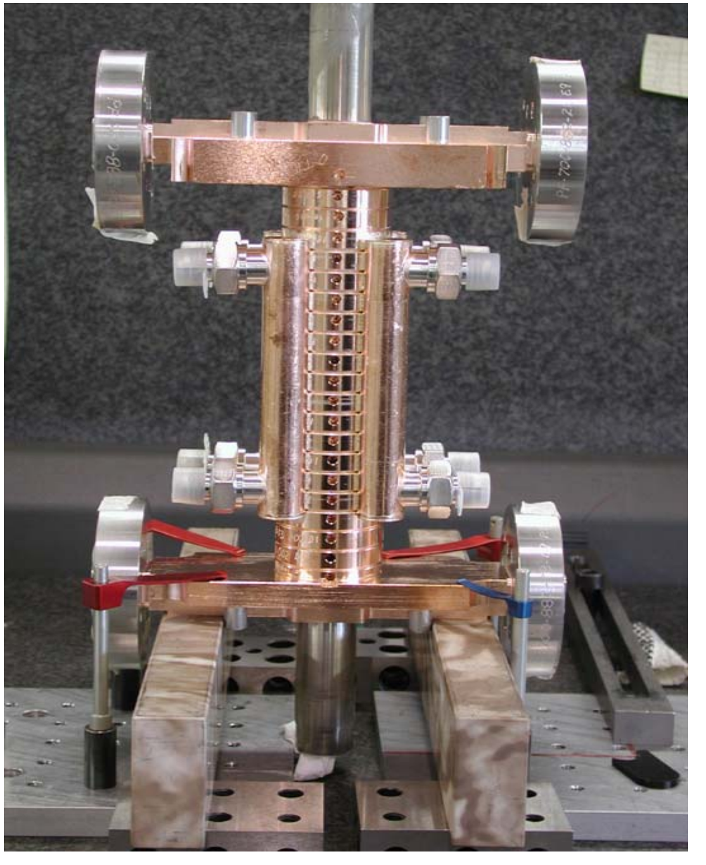




Mechanical Measurements of Structure

- Measurements Conducted
  - Structure Straightness
  - Perpendicularity of I/O Couplers to Disk Stack
  - Parallelism of I/O Coupler bodies to cover plates
  - Beam tube concentricity to Disk Stack
  - RF flange perpendicularity to coupler body
  - Rotational alignment of couplers to one another
  - Multiple leak checks

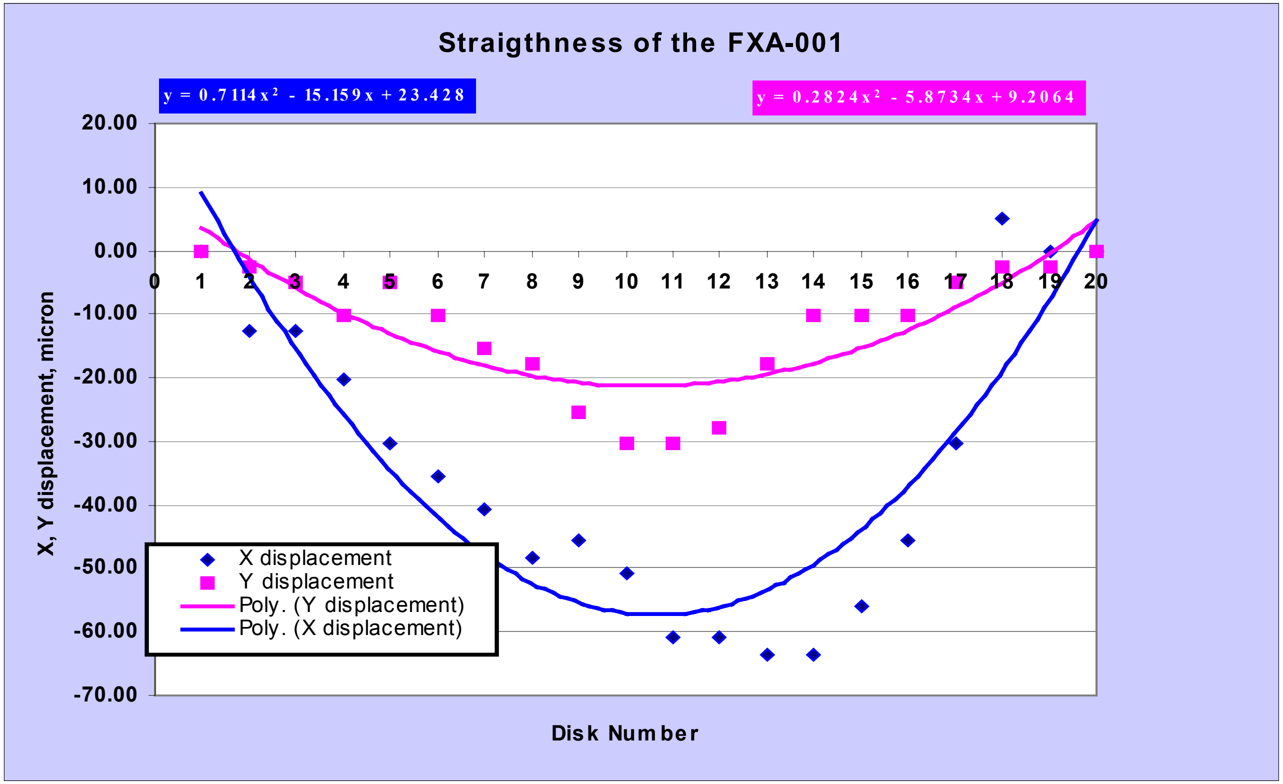
FXA-001 Setup for Mechanical QC at Fermilab Technical Division



(Tug Arkan)

Straightness QC on structure

Straightness FXA-001 is shown below. In new fixture FXA-002 stack was aligned and brazed in carbon V-block. Measured straightness 20 µm follows the straightness (bow) of V-block. In final structure about 20 µm jump between stack and coupler cells was found. It should be fixed on FXA-003.



RF Quality Control

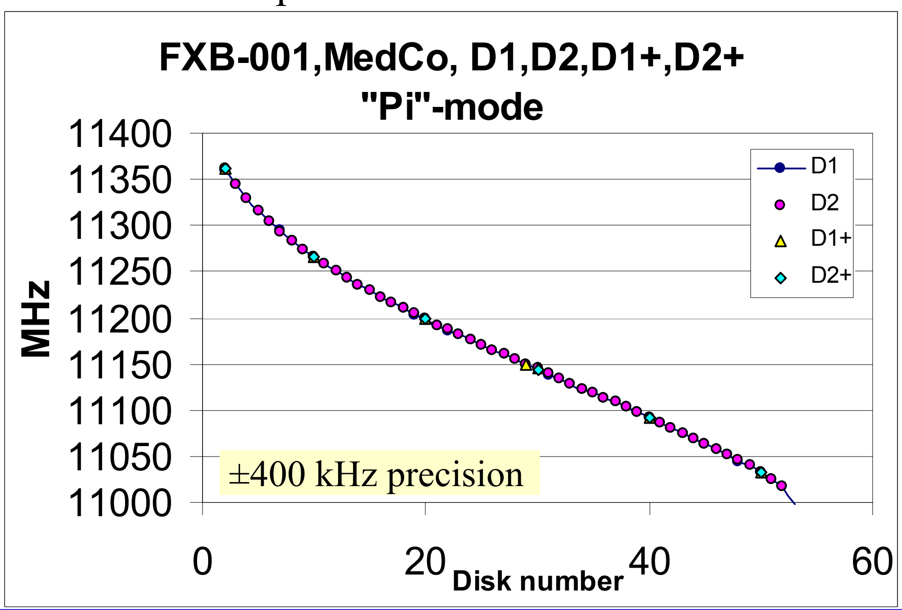
Developed few automated set-ups for RF measurements at different stages of structure production

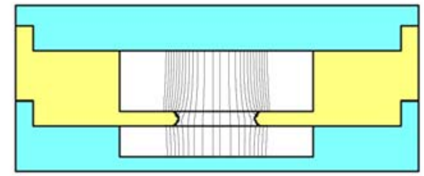
- Single disk and group of disks
  - New automated set-up
- Unbrazed/Brazed Disk Stack Plunger
  - Cells and group of cells frequencies
- Brazed Assembly Bead Pull
  - Including Structure Disk Tuning
- Vertically pulled plunger
  - (coupler tuning using Kahl method)

RF Quality Control (Disk measurement)

Automated Contact Set-up.

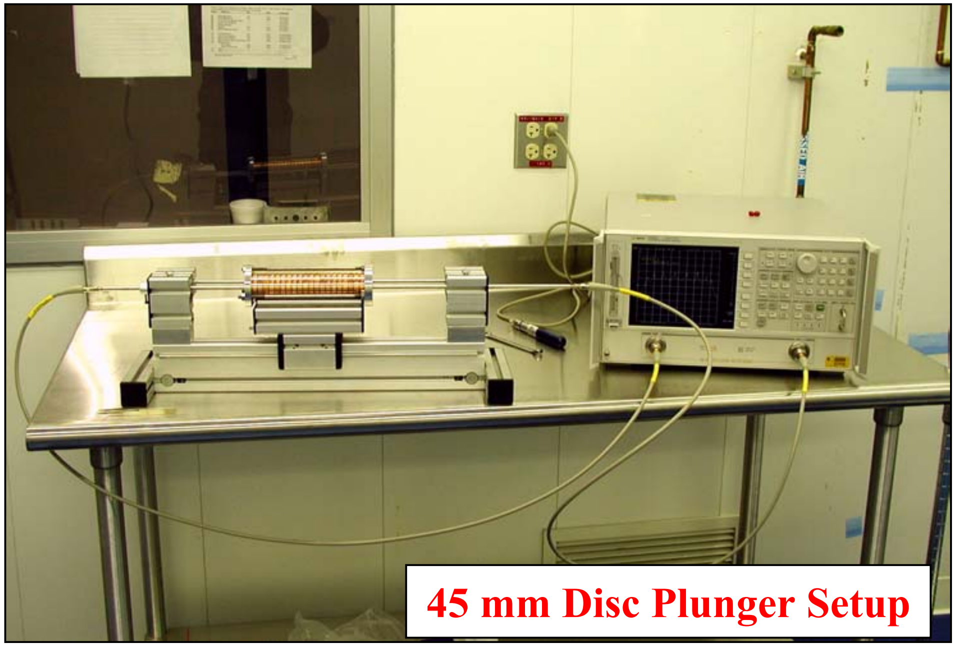
- Easy to install disk / set of disks. Fixed pressure.
- Automated search and reading own frequencies, Q's
  (0 - mode, π-mode and two first dipole modes)
- Collecting, plotting and saving all data in Excell file.
- Temperature stabilization in room, humidity and air
pressure are controlled (not automated).
- Master disks for reference.
- 0.5-1 minute/per disk

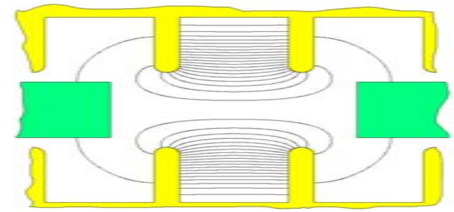


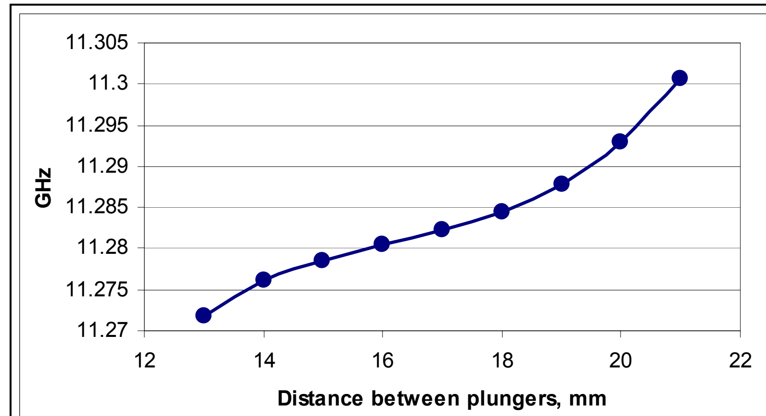


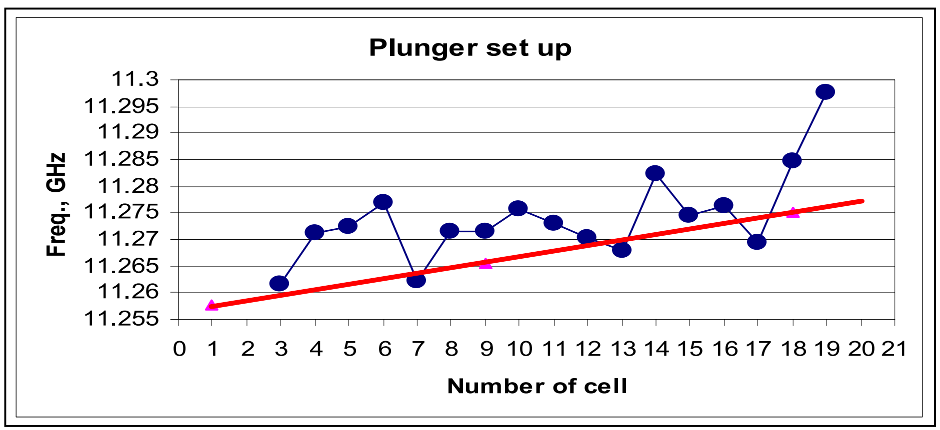
(From G.Romanov)

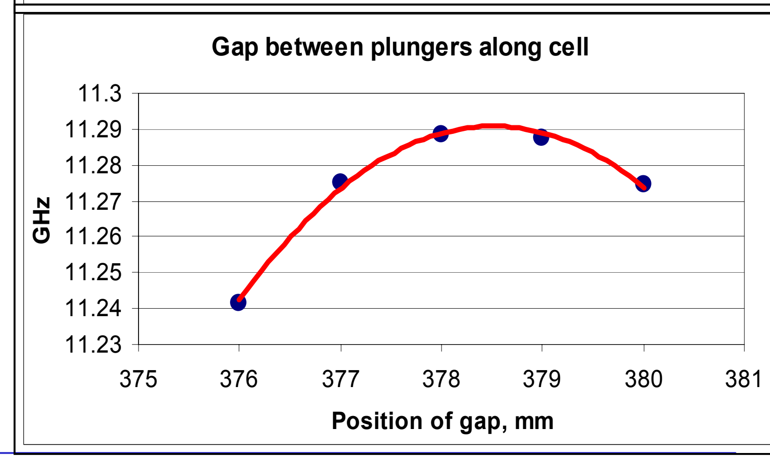
RF Quality Control (Plunger measurements)



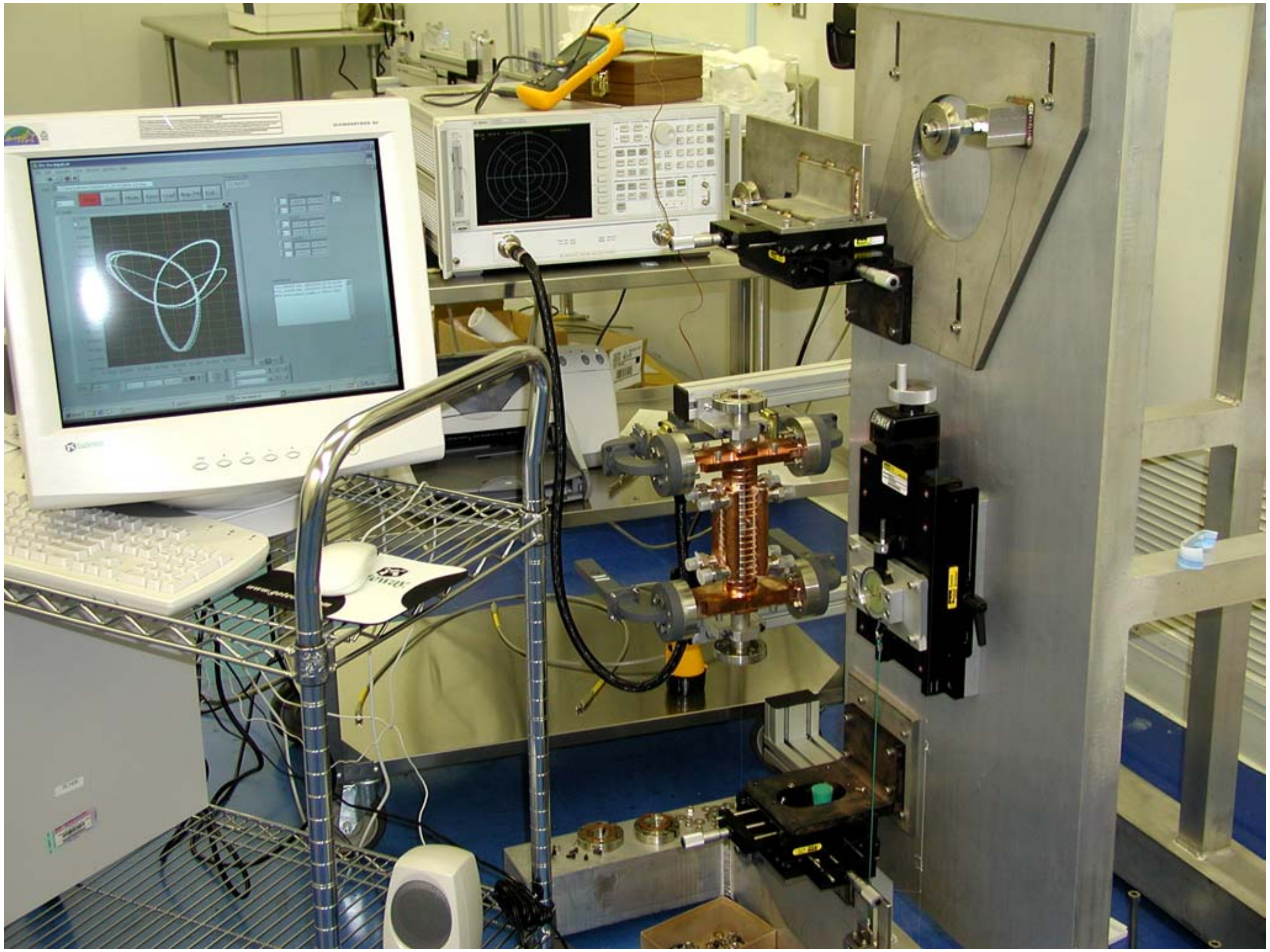








RF Quality Control (Bead-pull measurements)



Features

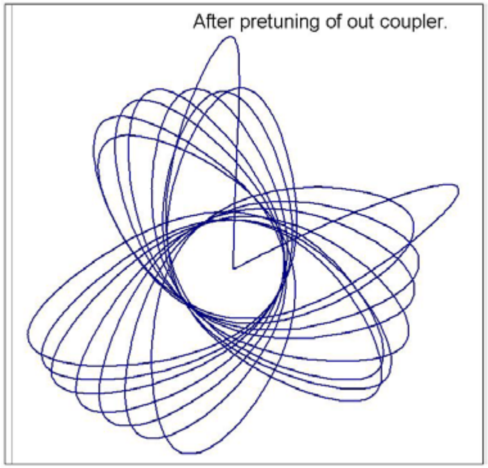
- **Network Analizer and step-motor are controlled by computer (LabView).**
- **Bead pull support**
- **Pulley**
- **Automated Reading data from NetAnalyzer.**
- **Data acquisition, analysis, plotting, saving**
- **Calculation of field and phase distribution, reflection from the cells and couplers.**
- **Automation of structure tuning process.**

(Temir Khabiboulline)

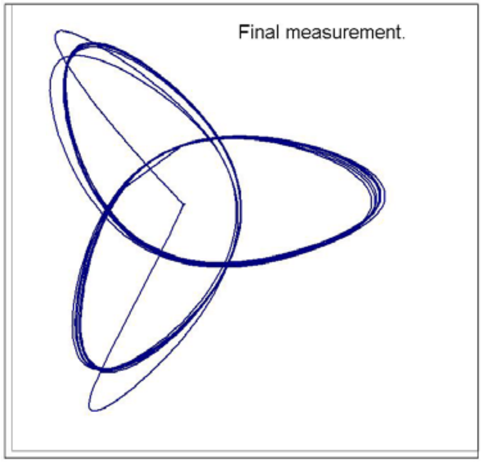
Tuning of FXA-002 Structure

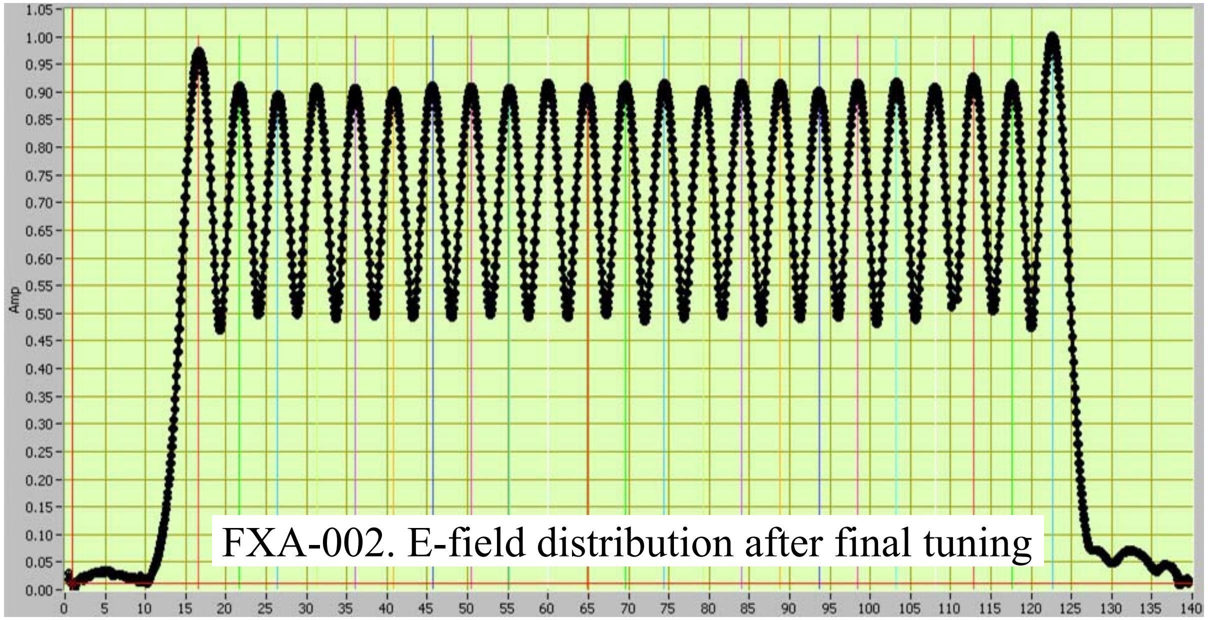
FXA-002 structure was measured and tuned after assembly using automated bead-pull set-up.
Plot of complex S_{11} parameter are shown before and after cells tuning. Output coupler was tuned first.
E-field distribution on structure axis measured after final tuning is shown below.

S11 before cell tuning

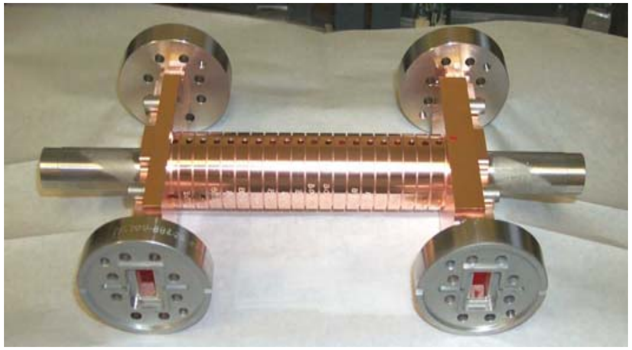


S11 after tuning



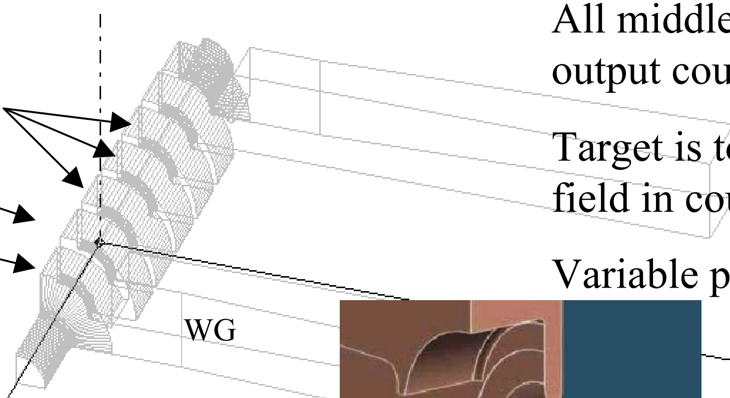


Simulation and optimization of Couplers for FXA Structure.



FXA structure are made according to SLAC's design of T20VG5 (5% group velocity). It is tapered 2pi/3 structure about 20 cm long, made of 20+3 cells

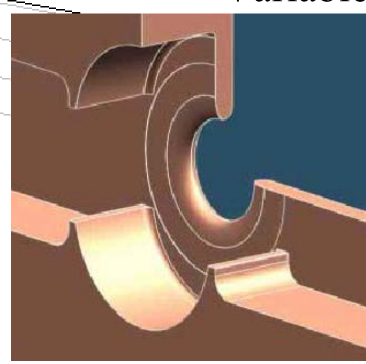
According to design, output coupler has one neighbor cell with radius bn. HFSS model have two identical (output or input) couplers with the same neighbor cell + 3 middle cells. All middle cells have geometry corresponding cell #20 (for output coupler model) or cell #1 (for input coupler).



Target is to get small reflection from coupler and reduce E-field in coupler cell.

Variable parameters in simulations are b_bn_w_a

- b - outer radius of coupler cell,
- bn – outer radius of cell neighboring to coupler
- 2w – slot width between coupler cell and WG
- a –iris radius between coupler and neighbor cells



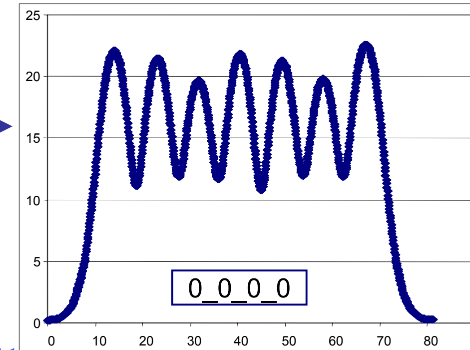
HFSS model of coupler (one quarter)

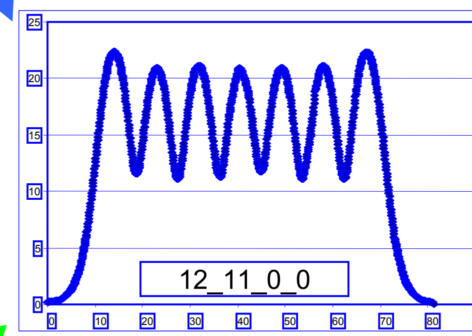
(I.Gonin, T.Khabiboulline)

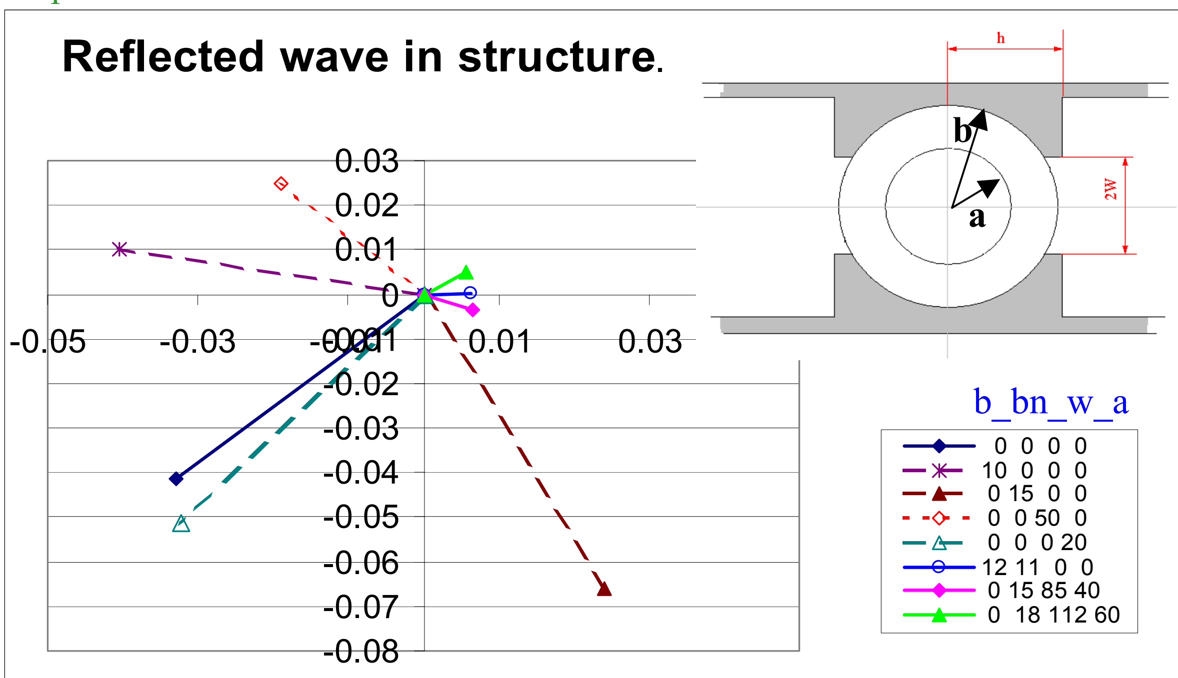
Output coupler. HFSS simulations.

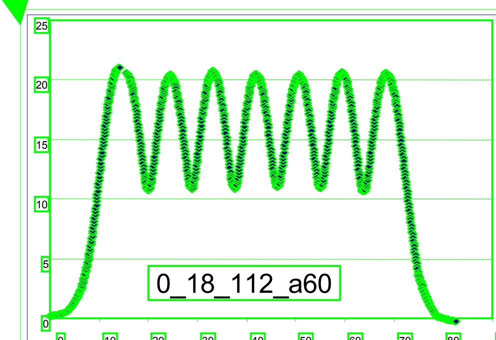
Designed coupler not matched. By linear combination of basic vectors (dashed lines) reflection from the coupler can be compensated (last three lines in table).

- Coupler with designed dimensions. Reflection S11 = 0.05.
- Reflection is compensated by changing cell frequencies Δb=12μm, Δbn=11μm, how we doing while tune coupler experimentally. E-field in coupler higher than in structure.
- Increasing coupling slot(w) and iris diameter(a) allowed to reduce E-field in coupler cell.



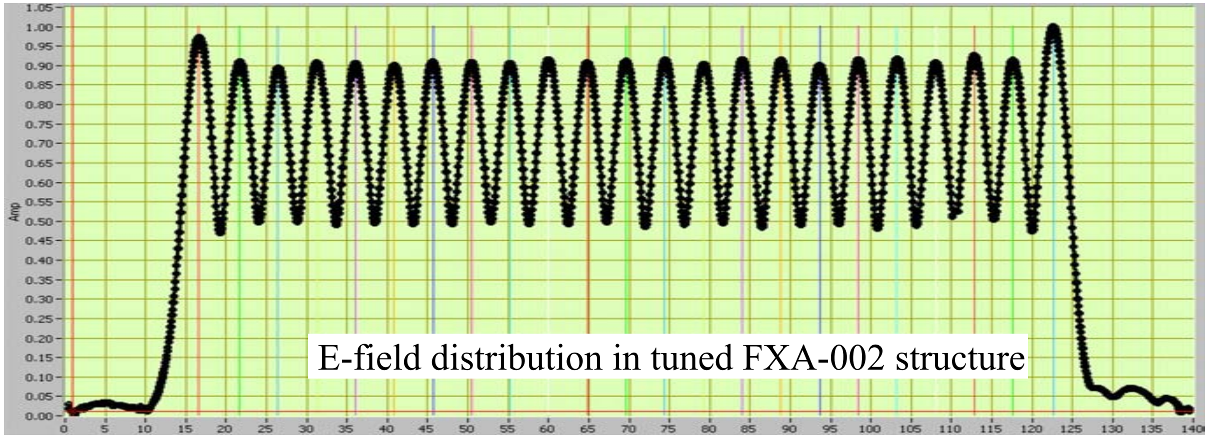




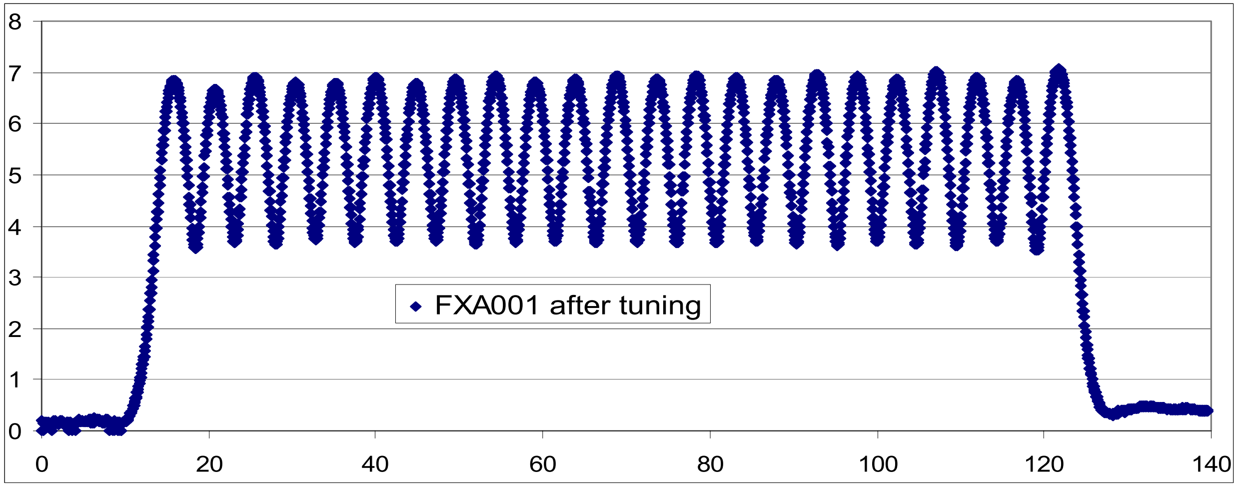


E-field distribution in tuned structure

Final E-field distribution of tuned FXA-002 structure shows a good agreement with HFSS simulations.



For tuned FXA-001 structure the E-field in coupler cells is lower. It can be explained by errors in iris shape in regular cells (50μm smaller effective iris diameter), while irises in input and output couplers were made by CMM without such error. It reduce cell-to-cell coupling and E-field in coupler cells.



Schedules and FY'02 plans

- **Complete Large Vacuum Furnace.**
  - Test, shipment, commissioning. Operational 07/2/02
- **Complete FXA-003. Finish 08/1/02.**
  - 20 cm long, conventional machined, high gradient, 45 mm OD
- **Make FXB-001 thru 003.**
  - 60 cm long, conventional machined, high gradient, 61 mm OD
  - 001- Finish 8/1/02, shipment to SLAC 8/7/02
  - 002/3 (24.5days) Arrives to SLAC by the end of August, 2002.
  - High gradient test at SLAC FXB-001 Aug-Dec. FXB-002/3 Jan-Mar,2003
- **Start to order parts for FXC.**
  - Close to Final NLC Main Linac Design
  - 60/90 cm long, assume diamond turned, real accelerators
  - Note: Need FXC design (including couplers) by July 2002 in order to deliver all structures to the 8 Pack test by December 2003

Future Plans: NLC in TD for FY03

In FY03 (need ~$3.3M to accomplish items below ---if flat funded, we just can't do it!):

- Make FXB-004 thru 009 (plus two extras)
  - Assume better coupler design than we had in FY01.
- Make FXC-001 thru 009 (plus two extras)
- See how many we actually have in mid to late FY03 and decide what to do in FY04

- Finalize NLC Girder Design and Make One (or two) for Installation in NLCTA

(from H.Carter)

Summary

- Two FXA-001&2 Structures built, measured and tuned at Fermilab.
- Developed hardware and software for precise RF QC and structure tuning.
- Improved cell tolerances and straightness of the structure.
- FXA-003 and FXB-001 thru 003 are under process of production.